METAL FINISHING CHECKLIST

The keys to pollution prevention in metal finishing are to minimize chemical dragout; minimize the amount of water used for rinsing; and recover, reuse, and recycle plating chemicals.

Sections:

I. Drag-Out Reduction and Recovery
II. Electroplating Solution Maintenance
III. Hazardous Chemical Replacement
IV. Rinsewater Reduction and Recycling

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.

I. Drag-Out Reduction and Recovery

For most plating shops, process solution drag-out and the subsequent contamination of rinse bath waters is a major problem. Issues include the loss of process chemicals and water and may generate additional wastes due to wastewater treatment processes.

Drag-out volumes vary depending upon the parts being plated, and whether barrel or rack plating is involved. For example, when a barrel emerges from a process tank, it typically drags out over 10 times more solution than a rack would.

Once drag-out volumes have been reduced to the lowest level practicable, drag-out recovery techniques can be used to recover process solution constituents from subsequent rinse baths.

Checklist

Q1. Does the facility have electroplating bath drag-out contamination of subsequent rinse baths or losses of chemical inventory due to a drag-out?
☐ Yes ☐ No
(If No, STOP)

Q2. Are there opportunities to control the plating solution, such as keeping:

a. The concentration low?	☐ Yes	☐ No
b. Increasing the temperature?	☐ Yes	☐ No
c. Using wetting agents?	☐ Yes	☐ No

Explanation: Plating Solutions
As the chemical content of a solution increases, its viscosity increases. In electroplating, more concentrated plating solutions lead to increased volumes being dragged out. Therefore, one suggestion would be to lower the concentration of the plating bath. In addition, increasing the bath temperature lowers its viscosity, and would therefore lower drag-out volumes. The third option to control the solution would be to use wetting agents, which reduce drag-out volumes by causing a reduction in the surface tension of the process solution.

Q3. Are parts racked or barrel-plated in such a way that the process bath solution is retained on the parts, rack, or barrel after removal from the bath?
☐ Yes ☐ No

Explanation: Rack or Barrel Modification
In principle, every object can be positioned on a rack in at least one way, to produce a minimum drag-out volume. For barrel plating, modifications can be made to the barrel to minimize drag-out.
Explanation: Work Piece Withdrawal Rate and Hang Time
The rate at which parts are withdrawn from the process tank has a major effect on drag-out quantities, due to viscosity forces. The recommendation would therefore be to slow withdrawal rates. Increasing the work piece hang time over the process tank allows for the drainage of some dragged out process solution back into the process tank.

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.

Q4. Do they use drainage boards or drip tanks between process tanks and rinse tanks?
☐ Yes ☐ No

Explanation: Drip Tanks or Drainage Board/Drip Shields
Drip tanks are the most basic form of drag-out recovery. They are simply empty tanks that collect process solution that drips after plating and before rinsing. Eventually, it is returned to the process tanks. Installing boards between process and rinse tanks will channel dragged-out solution back into the process tank.

Q5. Do they use air knives to force dragged-out solution back into the process tank?
☐ Yes ☐ No

Explanation: Air Knives
Air knives can direct an intensive stream of air at a part or rack, physically pushing the dragged-out solution form the work piece as it exits the process tank.

Q6. Does the facility use drag-in/drag-out rinsing?
☐ Yes ☐ No

Explanation: Drag-In/Drag-Out Rinsing
This technique involves rinsing parts in the same solution before and after plating. This results in plating chemicals being dragged into process tanks.

Q7. Is there an opportunity to recover process chemicals?
☐ Yes ☐ No

Explanation: Recovery of process chemicals:
7a. Vacuum or Atmospheric Evaporation
Vacuum or atmospheric evaporation is used to recover concentrated chemicals from large volumes of rinsewater. The chemicals can then be returned to the process tank.

7b. Electrowinning/Ion Exchange
Electrowinning is an electrolytic recovery method that removes platable heavy metals from concentrated solutions. It is not effective at low metal concentrations, and must therefore be used in combination with another method, such as ion exchange. Ion exchange is a chemical reaction in which an ion from the solution is exchanged for a like-charged ion attached to a stationary medium (i.e., resin) held in a column. When the capacity of the resin to exchange ions is reached, the exchanged ions can be removed and recovered.

7c. Reverse Osmosis
Reverse osmosis is a separation process that uses membranes to separate certain chemicals from the effluent waste stream. It is an ambient-temperature, low energy process and usually has low capital and operating costs when compared to other technologies.

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.

7d. Electrodialysis
Electrodialysis is often used for the recovery of nickel plating chemicals from a variety of nickel baths, including Watts, sulfamate, bright nickel and nickel galvanizing. Other applications include gold, copper, cadmium, trivalent chromium, silver, zinc cyanide, tin-lead, zinc galvanizing, and zinc phosphating.

Q8. What is the drainage time of the workpiece(s)? Has consideration been given to this time and the withdrawal rate in order to minimize the amount of dragout?

Explanation: Workpiece Withdrawal Rate and Drainage Time
The speed at which workpieces are removed from the process bath can have a substantial impact on dragout volume. The more slowly a workpiece is removed from the bath, the thinner the film of process solution is on the workpiece, and the less solution is dragged into rinse tanks. The effect is so significant that many experts believe that most of the time allowed for draining should instead be used for withdrawing the workpiece. A recent case study demonstrated that a drain time of 10 seconds reduced dragout by 40 percent compared to the industry average of 3 seconds (IAMS 1995). If necessary, lengthen the drag-out time so that it allows more chemicals to drip back to the process/bath tank and reduces the amount of chemicals introduced in the rinsewater.

Manual Operation

Q9. Do you have drainage times and withdrawal rates posted at tanks to remind employees?
☐ Yes ☐ No

Suggestion: Establish drainage times/withdrawal rates and post them at the tanks.

Q10. Do you have drip bars?
☐ Yes ☐ No

Explanation: Drip Bars
Drip bars allow personnel to drain parts hands free without waiting, so personnel will not use an insufficient drain time.

Q11. Is your company investigating the automation of the plating line or the drainage time?
☐ Yes ☐ No

Explanation: Line Automation
Eliminates possibility of employee with insufficient drain time and maintains product QA/QC standards if times are set properly.

General Tips:

To reduce the amount of drag-out, implement process changes such as withdrawing work pieces slowly, increasing hang times over process tanks, and installing drainage boards between process tanks and rinse tanks.

Most drag-out reduction techniques are easy and inexpensive to implement, and quickly pay for themselves through plating and processing chemical savings, as well as waste treatment and disposal savings.

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.

The costs to implement drag-out recovery techniques vary greatly. They may be off-set by the savings gained by reducing the amount of plating and processing chemicals necessary for make-up as well as reducing waste treatment and disposal savings.

Example:
A simple spray rinse drag-out recovery tank was installed on a decorative chrome plating line to reduce chromic acid drag-out losses. The capital costs were $2,500, and the annual operating cost savings were $5,440, resulting in a simple payback of 0.5 years (see http://www.p2iris.com/metalfinish/case01.htm).

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.

II. Electroplating Solution Maintenance

When process solutions decompose and lose key characteristics, or contaminants build up, they lose their effectiveness, and create quality and waste treatment/ disposal issues. This increases operating costs (e.g., labor and new plating solution costs) and disposal costs (e.g., spent plating solution).

Checklist

Q1. **Does the facility have problems maintaining their plating solution (e.g., do they have to dump the bath often, do contaminants build up)?**

☐ Yes **☐ No**
(If No, STOP)

Q2. a. Do they have sulfuric or hydrochloric acid pickling baths? ☐ Yes ☐ No

b. Do they have electropolishing baths using phosphoric? ☐ Yes ☐ No

c. Do they have nitric or sulfuric acid? ☐ Yes ☐ No

d. Do any plating rack or rework stripping with nitric acid? ☐ Yes ☐ No

e. Do they generate solutions from acid cycle cation exchangers? ☐ Yes ☐ No

f. Do they use continuous removal of acid from electrowinning solutions? ☐ Yes ☐ No

Explanation: Acid Sorption
Acid sorption is a solution maintenance technology that is used to maintain dilute to moderately concentrated acid solutions. Contaminated metal solutions are pumped through a bed of resin where the acid is absorbed and the metal salts pass through in a solution that can be treated or sent to an electrowinning process for metal recovery. The acid is then desorbed as water is pumped through the resin bed.

Q2. Are their chemical and water additions to process solutions controlled?
☐ Yes ☐ No

Explanation: Addition Control
The addition of excess chemicals, or the wrong chemicals, can require that the bath be decanted, filtered, purified, or even disposed of. The application of good operating procedures in the careful control of chemical additions can optimize process performance.

Q3. Does the facility use chemical precipitation to purify their process solutions?
☐ Yes ☐ No

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.

Explanation: Chemical Precipitation
Precipitation can be used to maintain zinc, nickel (both electrolytic and electroless), silver, bronze, and chromium plating baths. A variety of chemicals can be used, including barium or calcium hydroxide, barium or calcium cyanide, and calcium sulfate.

Q4. Do they have any of the following process solutions:

a. Mixed acids form stainless steel pickling baths? ☐ Yes ☐ No

b. Sulfuric/hydrochloric acid or sulfuric/nitric acid solutions for non-ferrous metal? ☐ Yes ☐ No

c. Hydrochloric and nitric acid stripping solution? ☐ Yes ☐ No

d. Sulfuric acid anodizing solutions? ☐ Yes ☐ No

Explanation: Diffusion Dialysis
Metal-contaminated acid solutions are passed over one side of an anion exchange membrane. A deionized water solution counterflows on the other side. Anions in the contaminated solution are transported across the membrane to the water side and the metal ions are blocked. Recovered acid is returned to the process bath, while the metal stream returned to the process bath, while the metal stream is sent to treatment or another recovery process.

Q5. Does the facility use electrolysis (dummying)?
☐ Yes ☐ No

Explanation: Electrolysis (Dummying)
Periodic or continuous electrolysis is used to remove metallic contamination – most often copper, tin, lead, and iron – to prevent serious levels of contamination in process baths. Dummying uses a cathode specific to the purpose (a "dummy") to plate out metallic contaminants. The resulting solids can either be treated, or sent to metal recovery.

Q6. Does the facility have:

a. Chromic acid? ☐ Yes ☐ No

b. Nitric acid strip? ☐ Yes ☐ No

c. Nitric/hydrofluoric pickle? ☐ Yes ☐ No

d. Sulfuric pickle? ☐ Yes ☐ No

e. Caustic etch baths? ☐ Yes ☐ No

f. Other? ☐ Yes ☐ No

Explanation: Porous Pots, Ion Transfer, or Membrane Electrolysis
These are similar, competing technologies applied mainly to the maintenance of chromic acid baths. The basic technology centers on the use of a membrane separating an anode

and cathode within the electrolytic cell. Membrane electrolysis can be used in nitric strip, nitric/hydrofluoric pickle, sulfuric and pickle, and caustic etch bath applications.

Q7. Is process bath filtration an option?
☐ Yes ☐ No

Explanation: Process Bath Filtration
Carbon filtration and prefiltration are bath maintenance techniques, used to remove suspended solids and organic contaminants. Contaminants removed include dirt, filter aids, and precipitates from bath purification or solution decomposition.

Q8. Are the raw materials of a sufficient purity level?
☐ Yes ☐ No

Q9. Is deionized water used?
☐ Yes ☐ No

Explanation: Pure Raw Materials and Deionized Water (For 9 and 10 above)
Use high quality raw materials and deionized water in the plating bath to reduce impurities, thus extending its life by minimizing the precipitation of minerals in water as sludge.

Q10. How often are process baths dumped?

Q11. What are labor and operating costs (e.g., costs for new chemicals/water) associated with preparing a new process tank?

Q12. What are the treatment/disposal costs associated with bath dumping?

Q13. Why are the baths dumped, (e.g. solution decomposition contaminants-which ones)?

Q14. Do you increase the bath temperature (except for cyanide and hex chromium baths)?
☐ Yes ☐ No

Bath Temperature Increase
Evaporates bath water so relatively clean waste rinsewater can be reused as bath makeup water. Reduces solution viscosity, so more chemical drains back to bath/process tank during dragout.

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.

General Tips

Depending upon the type of process solution, there are several techniques on the market that can purify/maintain process solutions to prevent premature disposal.

Examples:

- Acid sorption can reduce acid usage by about 30-65%. The by-product is hazardous waste sludge, unless the metals are reclaimed through electrowinning. Equipment costs for sulfuric acid anodizing applications are $35,000 - $40,000. Installation costs are 10-35% of equipment costs. Operating costs for sulfuric acid application are $7/pound of aluminum removed for a unit operating at 10g aluminum/liter.
- Porous pot units cost under $800. Multiple pots may be required. Operating and maintenance labor requirements are in the 26-260 hour/year. Non-labor costs range from $100-500/year.
- Polyfluorocarbon ion transfer units cost in the $10,000-30,000 range, while operating costs are in the $5-27 per pound of iron removed, depending upon the level of bath contamination.
- Membrane electrolysis equipment costs are in the $20,000-70,000 range for metal removal of up to 300 grams/day. For metal removal of up to 1,200 g/day, equipment costs are in the $100,000-300,000 range. Annual operating costs are in the $5,000-10,000 range.

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.

III. Hazardous Chemical Replacement

The use of cadmium, hexavalent chromium, or cyanide in the electroplating process involves many issues, including employee exposure, air quality, and hazardous waste treatment and disposal.

Cadmium, hexavalent chromium, and cyanide metals have been described as being toxic to both human health and the environment. Plating processes that use these chemicals face high pollution control costs (e.g., scrubbers, waste treatment systems, disposal) and must manage worker exposures to these toxics. As a result, the plating industry and the regulatory community are investigating alternative processes.

Checklist

Q1. Does the facility use hazardous chemicals such as cadmium, hexavalent chromium and/or cyanide in their plating processes?

☐ Yes ☐ No
(If No, STOP)

Q2. Have alternatives to cadmium, chromium, or cyanide been investigated?
☐ Yes ☐ No

Explanation: Cadmium Plating Alternatives
Cadmium plating is often used for fasteners and other tight tolerance parts, due mainly to its excellent lubricity and corrosion-resistance characteristics. Although no single alternative is an exact replacement, three alternatives should be considered: tin/tin alloy, zinc alloy, and aluminum coatings applied by ion vapor deposition.

Explanation: Hexavalent (Hard Chrome) Chromium Plating Alternatives
Hexavalent chromium plating is typically applied to cylinder liners and pistons for internal combustion engines and cylinders and rams for hydraulic pistons due to its excellent wear- and temperature- resistance characteristics. Alternatives include:

- Physical vapor deposition
- Tin-nickel
- Trivalent chromium

Explanation: Cyanide Use Alternatives
Cyanide salts are often used in copper, zinc, cadmium, silver, and gold electroplating baths, among others. Cyanides can also be used in the stripping process, especially nickel stripping. Alternatives include:

- Acid chloride zinc
- Alkaline non-cyanide zinc
- Tin/tin alloys
- Aluminum coatings applied by iron vapor deposition
- Zinc alloy
- Non-cyanide stripping solutions

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.

Q3. Which chemistry is used and why is it used (e.g., decorative, corrosion-resistance, etc.)?

Q4. What types of parts and metals are being plated?

Q5. What are company and customer requirements for product finishes?

General Tips

One possible solution would be to investigate the replacement of these chemicals with other established or emerging electroplating processes.

Savings related to replacing hazardous chemicals may be realized through purchase costs of chemicals, analytical expenses, treatment and disposal costs.

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.

IV. Rinsewater Reduction and Recycling

In an electroplating process, excess use of rinsewater increases water and sewer costs, as well as wastewater treatment costs. Reducing this use could:

- Lower operating costs by reducing water/sewer bills
- Reduce the quantity of treatment chemicals used
- Improve the removal efficiency of the waste treatment system
- Reduce the need for future end-of-the-pipe treatment and recovery systems

Once rinsewater reduction techniques have been implemented to the fullest extent feasible, recycling or reuse of rinsewaters can further reduce water, sewer, and wastewater treatment costs. Excessive use of rinsewater increases water/sewer and wastewater treatment costs, and may increase the regulatory burden.

Q1. Does the facility think that they use an excessive amount of rinsewater, as evidenced by water/sewer bills and/or wastewater treatment costs?

☐ Yes ☐ No

(If No, Stop)

Q2. Are there opportunities to improve the design of existing rinsewater tanks, such as adding a flow distributor or agitator?

☐ Yes ☐ No

Explanation: Optional Rinse Tank Design

To minimize the use of water:

- Select the minimum size rinse tank in which parts can be rinsed and use the same size tank throughout the line.
- Use a flow distributor/sprayer to feed rinsewater evenly.
- Use air agitation, mechanical mixing, or other means of mixing.

Q3. Are there opportunities to limit the amount of rinsewater being used, such as flow restrictors, timer rinse controls, etc.?

☐ Yes ☐ No

Explanation: Rinsewater Use Control

To minimize the use of water:

- Install flow resrictors.
- Apply manual control of water.
- Install conductivity controls.
- Install a solenoid valve on automated plating machines.
- Install timer rinse controls.
- Install flow meters and accumulators.

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.

Q4. Are there opportunities to use alternate rinsing configurations, such as spray rinsing, counterflow rinsing, etc.?

☐ Yes ☐ No

Explanation: Alternate Rinsing Configurations

Alternate rinsing configurations, such as spray, cascade (e.g., counterflow), reactive, static, multiple-stage, and dual-purpose rinsing, can reduce rinsewater use as well.

Q5. Are oil or free-standing solids present in the wastewater?

☐ Yes ☐ No

Explanation: Coalescer or Oil Skimmer

With a coalescar, contaminated water is pumped through a separation chamber containing an oil-attracting medium with high surface area. Lighter materials agglomerate in the oil storage zone in the top of the unit. Solids settle to the sludge storage zone on the bottom of the unit. The unit can be followed with a bag filter and other media to finish the water prior to recycling. Oil skimmers are often used in conjunction with coalescers in order to skim free-floating oils from the water.

Q6. Can waste rinsewater streams be segregated from other wastestreams to allow for the use of ion exchange prior to recycling?

☐ Yes ☐ No

Explanation: Ion Exchange

Ion exchange units are often used to treat waste rinsewater prior to recycling. As rinsewaters are passed through a bed containing a resin, the resin exchanges ions with inorganic compounds in the rinsewater. The metals are then recovered from the resin and the water can be returned to the resin system. Filtration can be used prior to the unit and a water polisher can flow it.

Q7. Have they investigated the use of ion exchange, reverse osmosis, or electrodialysis in order to recycle rinsewater?

☐ Yes ☐ No

Explanation:

7a. Reverse Osmosis

Reverse osmosis systems use a semi-permeable membrane that permits the passage of purified water while not allowing certain components to pass through. The rinsewater can be returned to the rinse system, while the components can be returned to the process bath.

7b. Electrodialysis

Electrodialysis is used to concentrate ionic components contained in the rinsewater so they can be returned to the process bath. The rinsewater can be returned to the rinse system.

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.

7c. Segregate Rinsewater Waste Streams
Segregating waste streams can improve the efficiency of rinsewater recycling systems.

Q8. How much rinsewater is being generated?

Q9. What are the unit costs or annual costs for water and sewer service?

Q10. What are the unit costs or annual costs for wastewater treatment?

Q11. Do you have a static rinse that follows the plating bath/process tank?
☐ Yes ☐ No

Explanation: Static Rinse
This rinse captures the most concentrated dragout for returning to the plating bath or for metal recovery.

Q12. Have you considered or already installed conductivity meters?
☐ Yes ☐ No

Explanation: Conductivity Meters
Platers can use conductivity meters in place of flow restrictors on a rinse system where dragin is highly variable or where monitoring the bath for extreme conditions (over or under concentration) is desirable. These meters control water flow through a rinse system by means of a conductivity sensor that measures the level of ions in the rinsewater. When the ion level reaches a preset minimum, the sensor activates a valve that shuts off the flow of fresh water into the rinse system. When the concentration builds to a preset maximum level, the sensor opens a valve to resume the flow of fresh water. These meters can alert production line staff to imbalances in rinsewater concentration so that they can be replenished on an as-needed rather than a continuous basis.

Q13. Do you use a foot pump or photo sensor to activate rinsing?
☐ Yes ☐ No

Note: These items allow use of sensor to activate rinsewater only when processing parts. A photosensor may be used on automatic plating lines.

General Tips
Reducing the amount of rinsewater used can be considered to be "source reduction", which is the preferred method according to the EPA'a hierarchy of waste reduction/pollution prevention.

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.

Recycling or reusing the water would be the next best option, with treatment the least preferred method.

Examples

- A 3-gallon per minute (gpm) coalescer costs about $5,000, while a 20-gpm unit costs about $10,000, including pump and filter regulator.
- One plant reported that installation of a coalescing unit cut their cleaning times in half and reduced cleaning tank dumps from 6-8 times/year to once/year (see http://www.p2iris.com/metalfinish/1322-w.htm).
- A small California job shop electroplater installed an ion exchange/evaporator system in an effort to achieve zero-discharge. Prior to this installation, their annual operating costs were about $29/1,000 gallons of rinsewater. Through the use of the system, this was reduced to $6 – 8/1,000 gallons of rinsewater (see http://www.p2iris.com/metalfinish/1601-cs.htm).
- A major, multinational manufacturing company installed an ion exchange system and reduced their annual operating costs from $36,900 to $17,500 (see http://www.p2iris.com/metalfinsh/case03.htm).

Sources: Michigan Manufacturing Technology Center, 2/99 and CSDLA, 12/90.